MINING SAFETY AND HEALTH FOCUS

NIOSH

Vol. 4, No. 1 — The latest developments in Federal mine safety and health research — February 1999

New Directors Appointed at NIOSH Mining Research Labs

JEFFERY KOHLER
Pittsburgh

ROS HILL
Spokane

THE NATIONAL INSTITUTE for Occupational Safety and Health (NIOSH) recently announced the appointment of directors for its mining safety and health research laboratories in Pittsburgh, PA, and Spokane, WA.

Following a broad national search, Jeffery L. Kohler, Ph.D., and John R. M. (Ros) Hill were selected as the first permanent directors of the NIOSH Pittsburgh and Spokane Research Laboratories, respectively.

"Dr. Kohler and Mr. Hill have excellent credentials," said R. Larry Grayson, Ph.D., Associate Director for Mining. "They each bring important skills, insights, and a team-building perspective essential to developing a quality mining research program. Their selections were a major step toward achieving organizational stability and realizing the synergy envisioned by NIOSH 2 years ago."

CONTINUED ON PAGE 2

Preventing Hearing Loss Among Miners

PROLONGED EXPOSURE TO hazardous noise levels over a period of several years generally causes permanent damage to the auditory nerve; the greater the noise exposure, the more rapid the loss. Unfortunately, the loss of hearing acuity occurs gradually and is so subtle that an individual may not realize it until a substantial amount of hearing is lost. This damage, known as noise-induced hearing loss (NIHL), is a permanent, chronic, and *irreversible* health effect. Once the damage has occurred, there is no known medical

CONTINUED ON PAGE 2

This issue's focus:

HEARING LOSS PREVENTION
DUST AND DIESEL EXHAUST MEASUREMENT
CHEMICAL HAZARDS

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

CDC
CENTERS FOR DISEASE CONTROL AND PREVENTION

New Directors Appointed at NIOSH Mining Research Labs

CONTINUED FROM PAGE 1

Dr. Kohler, Associate Professor of Mining Engineering at The Pennsylvania State University, has been associated with mining-related research, consulting, and academia since 1974. He is author or coauthor of 22 peer-reviewed journal articles, 3 U.S. Bureau of Mines (USBM) and NIOSH Reports of Investigation or Information Circulars, 24 research contract reports, and 40 other publications. His research has included such areas as mine power systems, electrical grounding, electrocutions in the mining industry, detection of incipient electrical component failures, sensors for mine monitoring, mine ventilation, expert systems applications, and noise control. Most of his work has focused on the underground coal and aggregates industries, but his projects have also spanned both surface and underground mines of the metal/nonmetal industry.

Dr. Kohler has been active in both the Institute of Electrical and Electronics Engineers-Industrial Applications Society (IEEE-IAS) and the Society for Mining, Metallurgy, and Exploration, Inc. (SME). He received B.S., M.S., and Ph.D. degrees in 1974, 1977, and 1983, respectively, from The Pennsylvania State University.

Mr. Hill has served as acting laboratory director at the NIOSH Spokane Research Laboratory since 1996. Since 1996, he was the research supervisor for the mine safety and health group at the lab. He has been involved in mine safety and health research since joining the former USBM in 1971. Mr. Hill has published extensively in both national and international forums and has served as chair or organizing committee member for more than a dozen technical sessions at conferences worldwide. Research interests include ground control and rock bolting, rock mechanics, mine backfilling and safe disposal of mine wastes, and safe operation of mining equipment through automation.

Mr. Hill has been active in SME and the Northwest Mining Association. He received his Professional Geological Engineer degree from the Colorado School of Mines. He is a member of the American Institute of Professional Geologists and is a Certified Professional Geologist. ■

MINING SAFETY AND HEALTH

FOCUS

NIOSH

Mining Safety and Health Focus is published by the—

National Institute for Occupational Safety and Health
Pittsburgh Research Laboratory
Cochrans Mill Rd.
P.O. Box 18070
Pittsburgh, PA (USA) 15236-0070
FAX: (412) 892-6614

National Institute for Occupational Safety and Health
Spokane Research Laboratory
315 East Montgomery Ave.
Spokane, WA (USA) 99207
FAX: (509) 354-8099

Editor-in-Chief, Robert J. Tuchman (412) 892-6611 (rgt2@cdc.gov).

Spokane Research Laboratory Editor, Priscilla Wopat, (509) 354-8084 (pdw8@cdc.gov).

Graphics Design, Marianne Miller (412) 892-6786 (zka7@cdc.gov).

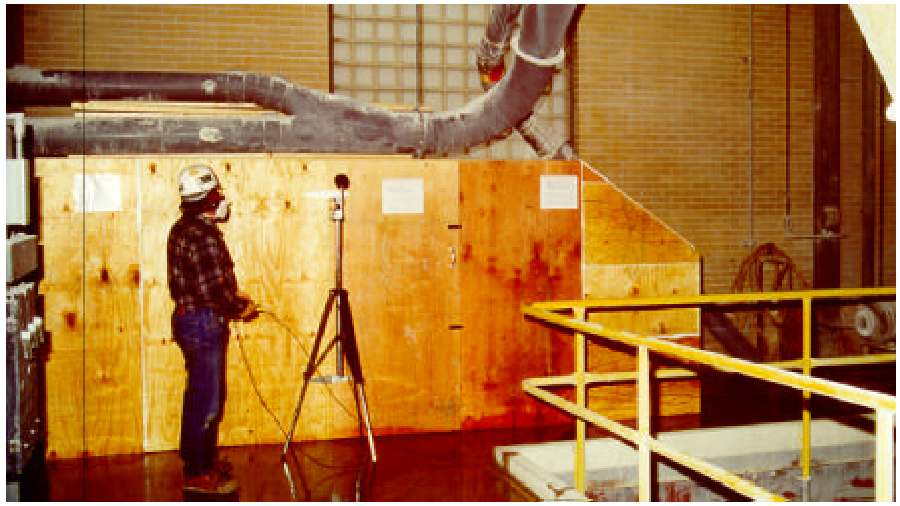
Additions, changes, or deletions to our mailing list should be directed to Rose Ann Crotsley, (412) 892-6609 (rkc6@cdc.gov)

Preventing Hearing Loss Among Miners

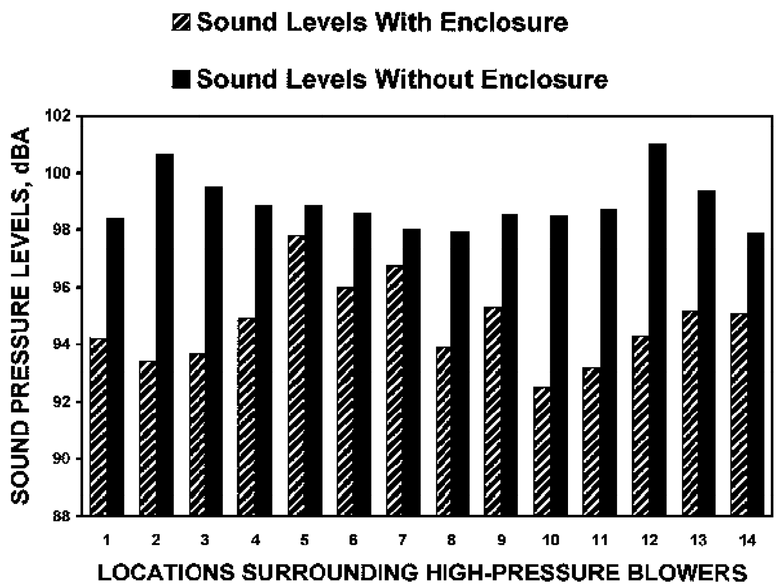
CONTINUED FROM PAGE 1

or surgical treatment that will restore the lost hearing acuity. Overexposure to noise remains a widespread, serious health hazard in the U.S. mining industry. The use of heavy equipment, the drilling of rock, and the confined work environment are just a few factors that contribute to high levels of noise exposure in the mining industry. A recent NIOSH analysis of a large sample of audiograms showed that at age 50 about 90% of coal miners and 49% of metal/nonmetal miners had a hearing impairment. By contrast, only 10% of the nonoccupational-noise-exposed population (as defined by Annex A of ISO-1999.2) had a hearing impairment at age 50. NIOSH has recognized NIHL as one of the 10 leading work-related diseases and injuries in the Nation, and its importance is expressed in the National Occupational Research Agenda developed by NIOSH and the occupational safety and health community.

One goal of the Hearing Loss Prevention Branch at the NIOSH Pittsburgh Research Laboratory is to develop a program that will provide noise control techniques and, where applicable, equipment modifications that could reduce noise levels in order to prevent hearing loss among miners and maintain their quality of life. Technical assistance is envisioned to encompass noise surveys of equipment and operator exposure levels, laboratory analysis of the data, and, where applicable, control of specific mining noise problems. The level of assistance will range from simply providing information and on-site measurements to developing engineering solutions and participating in the implementation of retrofit noise control technology. Responses from the Mine Safety



Researcher recording acoustic measurements near noise-reducing plywood enclosure surrounding high-pressure air slide blowers.



Level of noise reduction with and without enclosure at 14 different locations near high-pressure blowers.

and Health Administration (MSHA) and stakeholder input, along with data from the cross-sectional survey research study, will identify where technical assistance may be necessary.

Currently, two intervention activities have been identified. The first is a research effort to assess noise levels associated with a pulverizing operation at a silica processing plant. Experiments to measure the spatial distribution of sound levels were conducted in the pulverizing mill building. Tests measuring the acoustic environment were performed using a recording system consisting of a microphone and preamplifier as input to a Nagra tape recorder. Noise data were recorded at various locations through the mill building. The recorded data were subsequently analyzed in the laboratory with a digital frequency analyzer. A 32- or 64-sec linear averaging time was utilized to calculate octave band spectra noise levels from 125 to 16,000 Hz and corresponding overall average noise levels. Results of the initial survey indicated excessively high noise levels around high-pressure air slide blowers located on the second floor of the mill building. A simple, cost-effective plywood enclosure lined with a 2-inch fiberglass acoustic material was constructed to reduce noise levels emitting from the high-pressure blowers. Results showed a significant reduction of noise in the immediate area surrounding the high-pressure blowers.

The second area of research, which was identified by MSHA, involves reducing the noise exposure levels of air-track drill operators. Currently, noise levels associated with the drill operators range from 100 to 110 dBA while operating from the drill mast location. This research project would assess noise levels of the surface drills by measuring the noise spectra at strategic locations around the drill. Retrofit cab technology at either the drill mast or tramming location has been identified as a possible solution to reducing operator exposure levels. Solutions ranging from simple partial barriers to complex full enclosures will be pursued and tested.

James P. Rider, Operations Research Analyst, (412) 892-4109 (jlr4@cdc.gov). ■

New Methods To Measure Respirable Dust

WORKERS IN MANY INDUSTRIES, especially mining, are exposed to dusts that can cause lung disease. Prolonged inhalation of respirable coal mine dust can lead to coal worker's pneumoconiosis ("black lung") and silicosis. These are debilitating diseases that cause untold suffering and economic hardship to those who provide our Nation the raw materials it needs. NIOSH, in partnership with industry, labor, and regulatory agencies, continues an aggressive campaign to eliminate these diseases through reduction of worker dust exposures. Historically, the adoption of permissible dust exposure levels into law and enforcing compliance with these levels has been a mainstay of reducing occupational exposures. Progressive companies try to prevent worker illnesses by educating workers about the hazards of respirable dusts and by adopting the best available engineering control technologies.

The ability to accurately measure dust levels is critical to assessing compliance with permissible exposure limits (PELs) and to evaluating the effectiveness of control technologies. However, monitoring dust levels in mining presents unique challenges because of the variable composition of the dusts and the constantly moving workplace. Currently, the most common method for assessing respirable dust levels in mining is the gravimetric method. During the work shift, a small battery-operated pump draws a known quantity of dusty air through a small particle-size classifier and deposits respirable-size particles on a collection filter. After sampling, the filter is mailed to a laboratory, where technicians weigh it to determine the mass of dust accumulated on the filter, then calculate the average concentration of dust that was in the sampled air. In practice, the current gravimetric method often takes several weeks before results are reported to the mine. This delay, coupled with the ever-changing workplace of the underground mine environment, makes the gravimetric measurement useful only as a historical data point. The results do not provide timely feedback to detect or correct excessively dusty conditions.

The NIOSH Pittsburgh Research Laboratory has been conducting important research in the area of dust monitoring and analysis. Following is a discussion of several research efforts to quickly and accurately measure and analyze hazardous aerosols that pose a health threat to our Nation's miners.

Machine-Mounted Continuous Respirable Dust Monitor

A recent NIOSH Criteria Document entitled "Occupational Exposure to Respirable Coal Mine Dust" lists improved sampling devices as a research need pertinent to coal miner respiratory health and prevention of disease. More specifically, the Report of the Secretary of Labor's Advisory Committee on the Elimination of Pneumoconiosis Among Coal Mine Workers recommended the development of *continuous* respirable dust monitors to help protect workers' health. The NIOSH Pittsburgh Research Laboratory is developing a machine-mounted continuous respirable dust monitor (MMCRDM) that can continuously monitor and record levels of respirable coal mine dust in mines to an accuracy of ±25% with a 95% confidence level for at least 30 days without human intervention. The device is based on the tapered-element oscillating microbalance (TEOM®) sensing technology. It was developed to be mounted on mobile mining equipment and can continuously and accurately measure respirable coal mine dust mass concentrations despite the rigors of the mine environment. Readings of dust levels are stored in computer memory and displayed to the machine operator. The display shows dust levels averaged over various intervals and a graph of the shift average as a function of time. The monitor also incorporates several automatic diagnostic functions to detect system failure or tampering.

The TEOM® sensor in the MMCRDM uses a specially tapered, vibrating tube to measure the mass of dust sampled from mine air. This tube (tapered element) is hollow and made of metal. The wide end of the tube is firmly anchored; the narrow end supports a replaceable filter and is permitted to oscillate. By drawing air through the hollow tube, the monitor collects dust from the mine air on the filter. As the filter collects dust, its increase in mass causes the tapered element to vibrate more slowly. By measuring the change in frequency, an onboard computer calculates how much dust was collected on the filter. Unlike many aerosol measurement technologies (e.g., light scattering) that measure some aerosol parameter correlated with mass, the TEOM® technique measures mass directly. Used with a cyclone or other appropriate preclassifier, the instrument collects and measures respirable dust mass.

Laboratory and in-mine tests of earlier prototypes have been largely successful, with modifications to the instrument design cor-

Preproduction prototype MMCRDM.

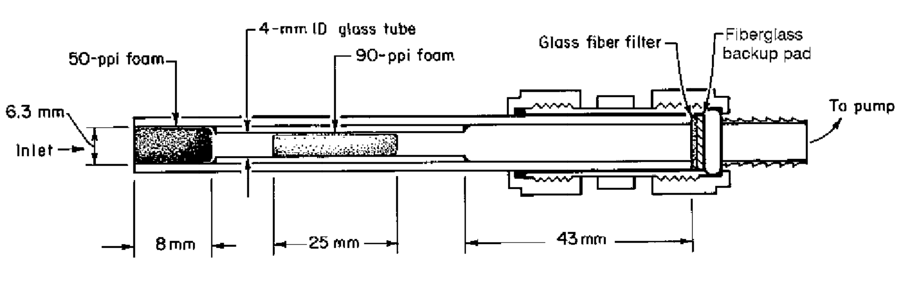
recting any problems identified during those tests. Production-version units are now being evaluated in underground U.S. mines. Researchers in other countries, such as Australia, have also expressed an interest in testing the device. Tests conducted thus far suggest that the MMCRDM is well received by working miners. In one particular case, miners used the readout of the MMCRDM to determine when to adjust ventilation on the section. Based on the promise of the MMCRDM, negotiations are currently underway to develop a person-wearable monitor based on the TEOM® measurement technology.

Personal Dust Dosimeter

An approach that is gaining favor throughout the exposure assessment community is providing individual workers with information about their *personal* dust exposure throughout the work shift. Providing such information empowers the worker to help reduce exposure. The NIOSH Pittsburgh Research Laboratory has developed a unique dust dosimeter that provides an inexpensive measurement of a worker's cumulative personal dust exposure during a shift. The dosimeter includes a dust detector tube that resembles the sorbent detector tubes used to measure exposure to various gases. This disposable, single-use tube contains a respirable-size classifier and a filter medium. It can be assembled for a few dollars per tube. This monitoring method may be useful as an inexpensive screening tool to alert workers to excessively high dust levels.

The device uses an inexpensive, commercially available, low-flow pump with an integral pressure transducer to draw dusty air through the tube. A section of porous foam removes large particles from the airstream and passes respirable dust onto a collection filter. The increase in differential pressure across the collection filter is related to the mass of dust collection on the filter. The correlation between the differential pressure across a filter and mass is not new. Recent work at the NIOSH Pittsburgh Research Laboratory demonstrated a linear pressure-versus-mass response for a specific filter medium. Concurrent work on the use of porous foam as a respirable dust classification medium lent itself to the disposable detector tube idea.

Results of laboratory testing of this device show promise. Six different coal dusts were aerosolized in a laboratory dust chamber, and a total of 119 triplicate observations comparing the dosimeter reading with gravimetric measurements were obtained. For individual coal types, the correlation coefficients, or agreement between the two methods, were between 0.90 and 0.97; 1.00 is a perfect correlation.



Dust detector tube.

The precision of the two methods was similar; the percent relative standard error of the personal samplers was 11.83% and that of the dosimeter was 13.96%. For all coal types tested, the data were best described by the power function $\Delta P = 1.43\ \text{mass}^{0.85}$, with a correlation coefficient of 0.73. The method becomes more accurate at higher dust loadings such that all laboratory data with mass loadings greater than an equivalent concentration of 2 mg/m^3 fall within ±25% of the power function. Assessment of the method under field conditions is underway.

The low-cost approach of the dosimeter lends itself to an increased number and frequency of samples that can be taken. Furthermore, the cumulative shift personal respirable dust exposure will be immediately available to workers, enabling timely modifications to procedures or implementation of additional dust controls to immediately reduce dust exposures. The reduced size, weight, and noise level of the new pumps may also encourage better worker acceptance of the new technique. Although slightly less accurate than other available measurement methods, the benefits of the new dosimeter may outweigh the need for high accuracy, especially for routine monitoring of many workplace environments.

Person-Wearable Sampler for Diesel Exhaust Particulate Matter

Diesel exhaust is a complex mixture of noxious gases such as carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, and sulfur dioxide; hundreds of different hydrocarbons (HCs); and diesel particulate matter (DPM). DPM is also a complex mixture of chemical compounds. It is composed of nonvolatile, elemental carbon, hundreds of different adsorbed or condensed HCs, sulfates, and trace quantities of metallic compounds. DPM is of special concern because it is entirely respirable in size; 90% of the particles, by mass, have an equivalent aerodynamic diameter of less than 1.0 µm. This means that the particles can penetrate the deepest regions of the lungs and, if retained, may cause or contribute to the development of lung disease.

Attention has focused on the potential carcinogenicity of DPM and the potential health impact on miners. In 1988, NIOSH recommended that whole diesel exhaust be regarded as a potential occupational carcinogen and stated that reductions in workplace exposure would reduce cancer risks. In 1989, the International Agency for Research on Cancer declared that "diesel engine exhaust is probably carcinogenic to humans."

In 1995, the American Conference of Governmental Industrial Hygienists (ACGIH) added DPM to the Notice of Intended Changes for 1995-96 with a threshold limit value (TLV®) recommendation of 0.15 mg/m^3. DPM smaller than 1.0 µm remains on the ACGIH Notice of Intended Changes in 1998. If this TLV® were adopted as a PEL, many mines using diesel equipment in the United States and Canada would be out of compliance.

Anticipating standards that regulate exposure to DPM and to facilitate research on its control, NIOSH developed a person-wearable sampler that can measure DPM selectively. Most DPM is less than about 0.8 µm in diameter; mineral particles are larger. The sampler consists of an impactor with a cut-point at 0.8 µm. Particles larger than 0.8 µm collect in the low-flow void immediately downstream of the impactor jet and are considered to be mineral particles. Particles smaller than 0.8 µm follow the airstream to the collection filter and are considered to be DPM. These samplers are being adapted for commercial production and will be available in fiscal year 1999.

On-Filter Analysis of Quartz

Airborne dust samples collected using the gravimetric method are often analyzed in laboratories to determined which percentage of the dust is quartz. In situations where the percentage of quartz exceeds 5%, the PEL for respirable coal mine dust is lowered from 2 mg/m^3 by the formula 10 ÷ percent quartz.

There is a span of time between the collection of dusts, the completion of quartz analyses, and action to correct overexposure situations. The NIOSH Pittsburgh Research Laboratory is conducting research that will shorten the time to correct overexposures. A new type of quartz analysis is being developed that can determine the amount of quartz dust on sample filters without the labor-intensive ashing or residue redeposition requirements of existing methods. After the sample is weighed at a laboratory, it is simply placed in a Fourier transform infrared (FTIR) spectrometer. The analysis can be completed in minutes using an unaltered sample. Sectors of the filter are scanned to average any uneven dust deposits on the filter that result from the sampling apparatus. Efforts are also underway to automate the procedure to achieve the most rapid and reliable analysis possible.

Bruce K. Cantrell, Ph.D., Research Physical Scientist, (412) 892-4019 (bec4@cdc.gov),

Jon C. Volkwein, Research Physical Scientist, (412) 892-6689 (jdv1@cdc.gov),

Donald P. Tuchman, Industrial Hygienist, (412) 892-6645 (det5@cdc.gov). ■

Rapid on-filter analysis of quartz dust is a goal of NIOSH research.

Assessment and Control of Exposures to Mercury and Silver

EXPOSURE TO METALS AND other chemicals in mining workplaces, particularly in milling and refining facilities, may adversely affect thousands of U.S. workers. Mercury and silver are examples of potentially hazardous metals found in ore deposits in the Western United States.

Mercury is not an important commodity, but it is retained during processing and refining because of its similarity to gold in chemical complexing and adsorption behavior. The potential for exposure is enhanced because mercury has a high vapor pressure, which means that whenever ore concentrates containing mercury are heated, the mercury is vaporized.

Exposure to silver and mercury can occur during numerous refining processes. Dust containing mercury or silver can be stirred up while handling dry concentrates or while cleaning silver bars (doré bars) after smelting. Also, metal fumes can be released when concentrates are heated during retorting and during smelting. Mercury or silver from the refinery can be spread to other areas on shoes or clothing.

Researchers from the NIOSH Spokane Research Laboratory and the Division of Surveillance, Hazard Evaluations, and Field Studies are conducting a series of case studies to characterize workers' exposures to mercury and silver during refining. The ultimate goal of this study is to improve the health of refinery workers by identifying existing technologies and work practices that reduce exposures to mercury and silver or by developing new ones. Surveys have been conducted at two silver-gold mines in the Western United States. Ore from these two mines is extracted from surface pits and crushed before it is leached with dilute cyanide solutions on impermeable heap leaching pads. Metals such as gold, silver, and mercury in the ore complex with cyanide to form soluble compounds that are carried in solution to a drainage collection system and eventually to the processing plant and refinery. The cyanide solution from the heap leaching pads is processed using the Merrill-Crowe process, which consists of clarification, de-aeration, and precipitation of precious metals onto zinc dust. The cyanide solution is then circulated through filter presses to separate the precious metals and zinc concentrate from the cyanide solution.

At Mine 1, retorting is conducted to remove mercury and dry the concentrates prior to refining. The mercury condensate is collected under water to minimize evaporation into the retort room. At Mine 2, a retort is not used; however, a propane torch is placed under the pans containing the concentrates to remove excess moisture prior to smelting.

Analyses of worker breathing-zone samples were used to characterize time-weighted average exposures, as well as exposures during specific tasks. Area samples helped to identify probable sources of exposures to be targeted by interventions. Finally, measurements in ventilation systems helped to determine the adequacy of the existing system and which modifications to the system should be made.

At Mine 1, the personal breathing zone samples for mercury were all below the permissible exposure limit (PEL) of 50 µg/m^3. The personal breathing zone samples for silver were all above the PEL of 10 µg/m^3. The results of area and personal samples for silver indicated important sources of exposure at the doré bar cleaning hood, slag cooling hood, and furnace. Appreciable silver exposures also probably occur while workers perform the tasks of sweeping concentrates around the top of the furnace back into the furnace, moving the retort trays onto and off of the scale during weighing, transferring concentrates to the furnace, and sweeping the floor around the furnace.

Two exhaust hood designs found in the American Conference of Governmental Industrial Hygienists Ventilation Manual were recommended as alternatives to the existing hood at the doré bar cleaning station. Both designs require that the gap in the back of the existing hood be covered to maximize capture of dust during bar cleaning. However, modifications made to the cleaning hood in November 1997 did not reduce silver exposure below the PEL.

CONTINUED ON BACK PAGE

Health Effects Associated With Mercury and Silver Exposure

Mercury

Acute Health Effects	*Chronic Health Effects*
Cough	Weakness and fatigue
Chest pain	Loss of appetite
Difficult breathing	Insomnia
Upset stomach	Depression
Headache	Tremors and shaking of hands, eyelids, and lips

Silver

Argyria (blue-gray discoloration of the skin, mucous membranes, eyes, and fingernails)
Chronic bronchitis
Decreased night vision

MINING SAFETY AND HEALTH FOCUS

NIOSH

CONTINUED FROM PAGE 7

Insufficient air flow and obstruction of the air intake with silver bars waiting to be cleaned limited the effectiveness of the modifications.

At Mine 2, two out of six personal breathing zone samples for mercury were above the PEL; eight out of nine personal breathing zone samples for silver were above the PEL. The area samples with the highest mercury concentrations were collected around the face of the furnace. Exposure to mercury could be controlled by first retorting the concentrates. A significant exposure to silver dust occurred when dried concentrate was dumped from drying pans into a hopper. The workers with the two highest silver concentrations were those performing this task.

Improved local and general ventilation and better materials-handling practices are the keys to reducing exposures to mercury and silver in the two refineries in this study. The method of drying concentrates at Mine 2 does not appear to release mercury; however, mercury exposure could be reduced or eliminated by retorting concentrates prior to smelting. A system similar to that used at Mine 1 to vacuum concentrates to the furnace should be implemented at Mine 2 for dust control. Finally, fundamental housekeeping practices and personal protection are essential for reducing exposures below the PELs for mercury and silver.

Pamela L. Drake, Research Chemist, (509) 354-8030 (pcd8@cdc.gov). ■

To receive other information about occupational safety and health problems, call 1-800-35-NIOSH (1-800-356-4674), or visit the NIOSH Home Page on the World Wide Web at http://www.cdc.gov/niosh

NIOSH
Pittsburgh Research Laboratory
Cochrans Mill Rd.
P.O. Box 18070
Pittsburgh, Pennsylvania 15236-0070